TIME AND MOTION STUDY OF A MANUAL ASSEMBLY LINE

PROJECT REPORT:NOOR METAL WORKS, GUJRANWALA

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Last but not least we would like to pay our gratitude and appreciation to our parents, family and special mates for their cooperation, encouragement and positive input.

EXECUTIVE SUMMARY

The Report is about Time and Motion Study of a Manual Assembly Line in Noor Metal Works, Gujranwala. Noor Metal Works, Gujranwala is explored in a briefed way. Its products, system and Production are observed. Manual Meat Mincer i.e., one of its Products is explained briefly and Assembly Line is carefully observed and discussed. The Motion and Time Study has been done on the Assembly Line of Manual Meat Mincer. Performance Measures are calculated and analyzed carefully. Line Balancing is done to improve the Assembly Line System and valid and feasible steps are taken to improve the system. Feasible and Valid Improvements Suggestions has also been discussed that can improve the Assembly Line.

1. INDUSTRY:

NOOR METAL WORKS GUJRANWALA

1.1 Location:

The Noor Metal Works Industry is at Mian Sansi Rd, Gujranwala.

2. Brief Introduction:

Noor Metal Works, Gujranwala is a well-establish industry in Pakistan that works on Batch Production System and supports Pakistan locally in Kitchen Utensils Products.

Noor Metal Works was established in **1995** and is continuously working to make its production process better. It is an **ISO-QAR** registered company holding ISO certification of **9001:2000**.



2.1 Major Products:

- Manual Meat Mincer
- Manual juice extraactor
- Tawa Pan

a) Tava Pan:

A tava (or sac is a large flat, concave or convex disc-shaped frying pan made from metal, usually sheet iron, cast iron, sheet steel or aluminum.. It also sometimes refers to ceramic frying pan.



Uses:
A *tava* or *saj* is used to bake a variety of leavened and unleavened flatbreads and pancakes In Pakistan, especially in rural areas, large convex *saj* are used to cook several breads at a same time or to make rumali roti.

b) Manual juice extractor:

A juicer (also known as juicing machine or juice extractor) is a tool used to extract juice from fruits, herbs, leafy greens and other types of vegetables. In manual juicer we use the hands to extract juice from fruits such as oranges.



3. Manual Meat Mincer (Selected Product):

A **meat grinder** is a kitchen appliance for fine chopping ('mincing') and/or mixing of raw or cooked meat, fish, vegetables or similar food. It replaces tools like the mincing knife, for example, which is also used to produce minced meat, filling, etc.



- **Parts:**

1. Grinder plate:

The grinder size is a number based on the diameter of the neck, outlet opening, and grinding plate that fits in the outlet opening. When you see them for sale, you will almost always see the number, usually with a # sign, showing the size.

Grinder Size	Outlet Diameter
#5	2 1/8"
#8	2 1/2"
#10 and #12	2 3/4"
#20 and #22	3 1/4"
#32	3 7/8"

This chart shows the most common grinder sizes and the corresponding measurement of the diameter of the cutting plate and outlet opening. The grinding plate, also called a cutting plate, is a round carbon or stainless steel plate with several holes in it that sits at the end of the meat grinder. As meat is forced through the holes of the grinding plate, a spinning blade cuts across the holes several times per second.

3. Auger:

It is made through two process

1. Casting
2. Milling

4. Cutting Blade Knife:

It is made through selective machining like milling

5. Grinding plate:

It is made through specific drills.

6. Locking Ring:

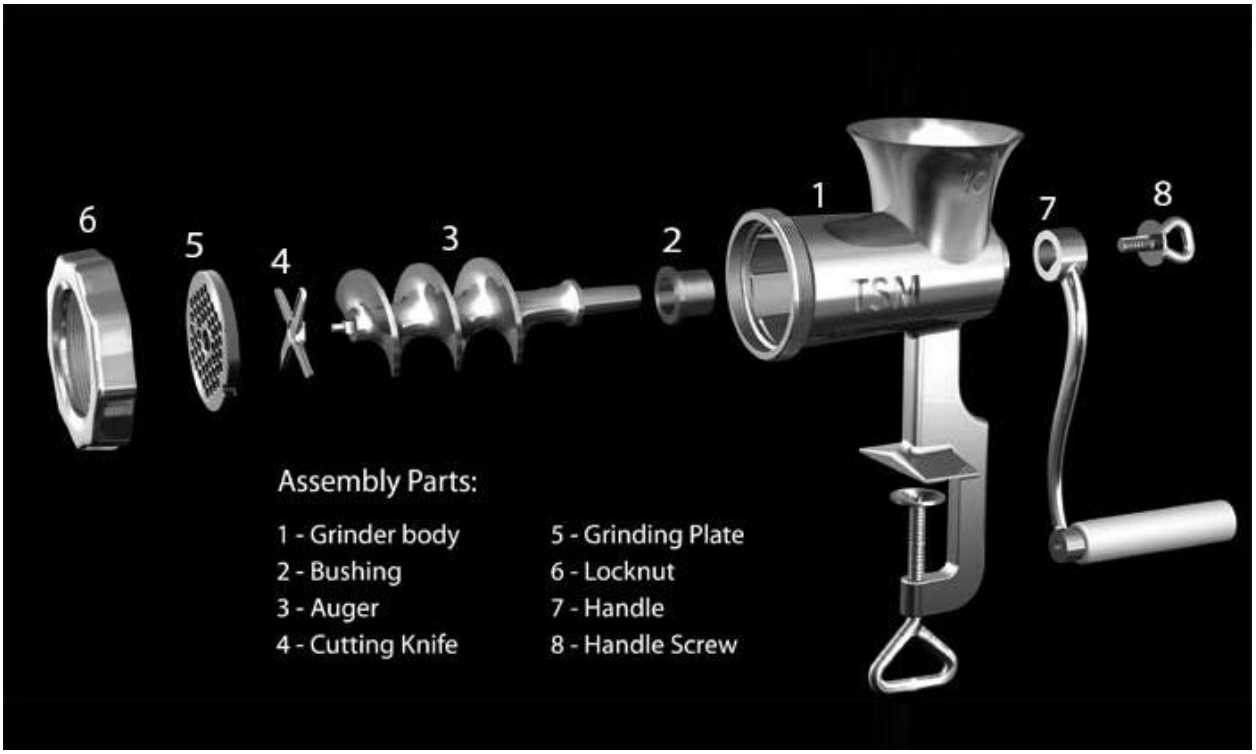
It is made through selective machining, turning, milling, threading etc.

7. Handle:

It is made purely through casting with a specific template.

8. Handle screw:

It is made through assembly process, a screw and a cover which may be of casting or machining.



- **Working:**

The producer puts the minced food into a funnel, which is placed on the top of the grinder. From there the material goes on a horizontal screw conveyor. This screw conveyor, which can be powered by a hand wheel or an electric motor, squashes and partially mixes the food. At the end of the screw, conveyor there is a knife installed directly in front of the fixed Grinding plate. At this opening the minced meat comes out of the machine. The fineness of the meat depends on the size of the holes of the plate.

By changing the Grinding plate it is also possible to produce breadcrumbs or fill sausage casing. After the drop from the retainer, it is possible to change the Grinding plate. By removing the fixing screw the grinder can be disassembled completely for cleaning. Besides the domestic manually or motor operated grinders, there are also grinders for butchery (table- or shop-grinders for example) and for the food industry. Some large machines are able to produce several tons per hour.

- **Manufacturing process:**

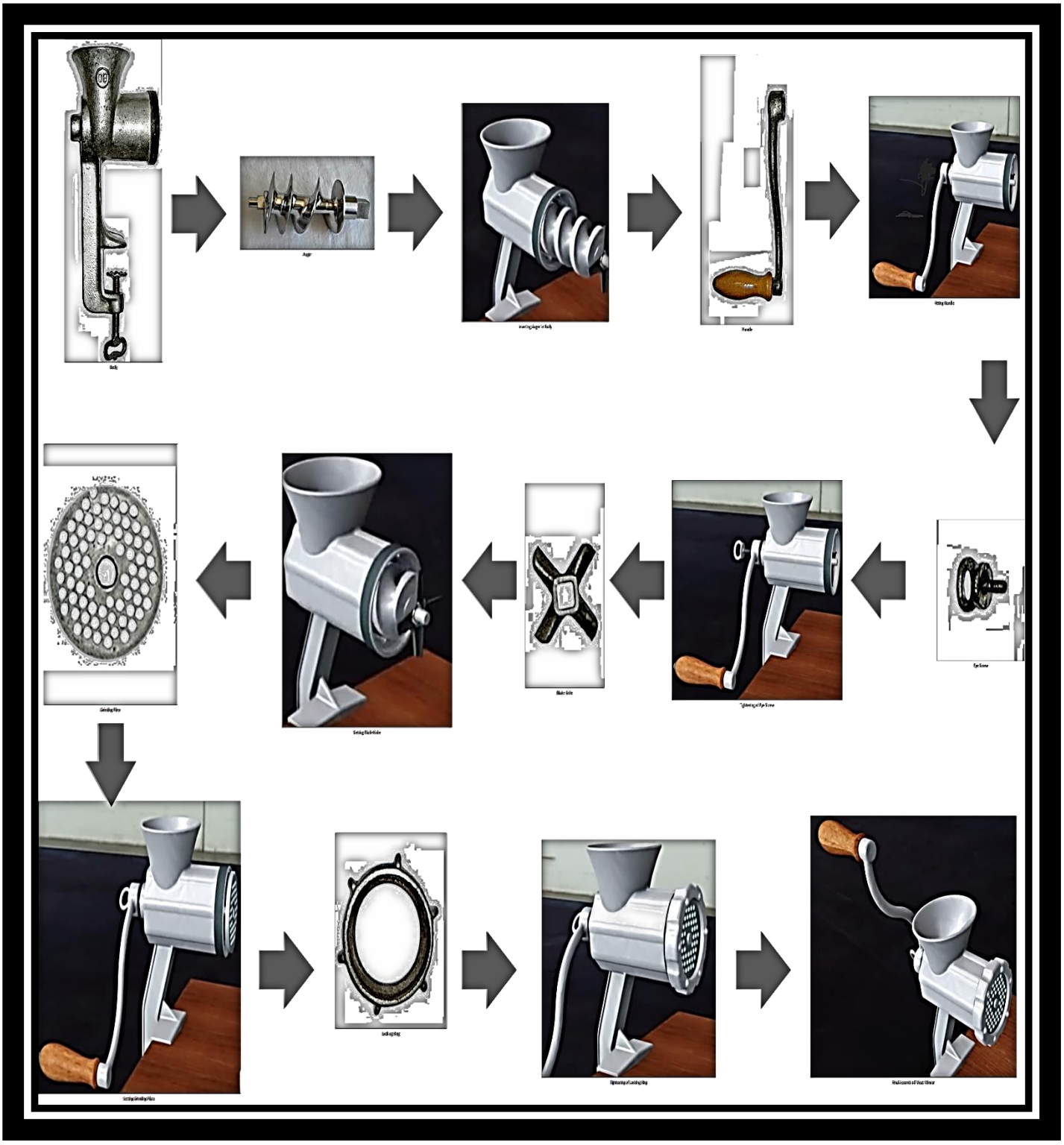
Manual meat mincer manufacture through following process:

1) First, Grinder body made through casting process
2) All of remaining tools such as auger, locknut etc. all are made through casting process
3) Cutter knife and grinding plate is made through machining process
4) After all of parts made casting parts are grinded to remove extra material.
5) Then they are polished in the end.





- **Assembly:**
 1) In first station, insert auger in grinder body.
 2) Then in second station, hold the handle and insert an eye screw in it. Tighten it at the back of body and pass it to next station.
 3) In third station, fix a grinding plate in front of cross knife.
 4) In the end station, fix a locking ring at the end of grinder body.



4. METHOD STUDY

- Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.
- Its aim is to find best possible manufacturing procedure that requires least time and less fatigue to worker.
 Used to analyze
 - Movement of body, people, or material
 - Activities of people & machines
- Method study is a technique to reduce the work content mainly by eliminating unnecessary movements by workers, materials, or equipments.

However, even after that, there could be unnecessary time taken for the process because of lack of management control or inaction of worker.

Explanation of Method study:

Various charts to record movements i.e. Process charts, SIMO chart etc.

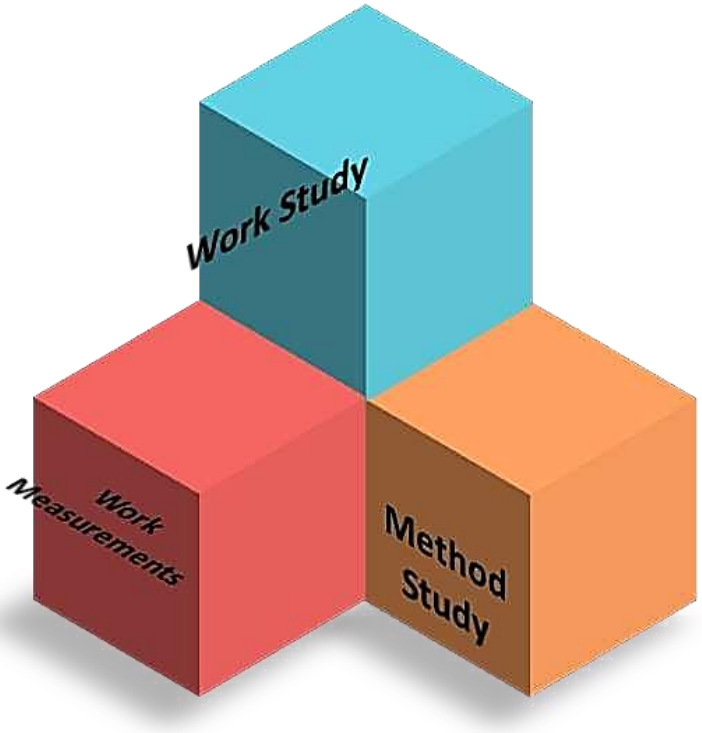
>> METHOD STUDY is a part of work study, hence to analyze method study we must know what **WORK STUDY** is.

5. WORK STUDY

Work Study is a generic term for management services and system engineering techniques, used to investigate:

>> Methods of performing work (**Method Study**).

>> The time taken to do it (**Work Measurement**).



- **OBJECTIVES OF METHOD STUDY**
 - Improvement of processes and procedures.
 - Improvement in the design of plant and equipment.
 - Improvement of layout.
 - Improvement in the use of men, materials and machines.
 - Economy in human effort and reduction of unnecessary fatigue.
 - Development of better working environment.

6. CHARTS IN METHOD STUDY

a) Operation Process Chart
b) Flow process chart (man, material and machine type)
c) Two handed process chart
d) SIMO CHART

- **METHOD STUDY APPLICATIONS**

1) The need for methods analysis can come from a number of different sources :
2) Changes in tools and equipment.
3) Changes in product design or new products.
4) Changes in materials or procedures
5) Other factors (e.g. accidents, quality problems)

- **RECORDING TECHNIQUES**

 - **Charts**

1) Outline process chart

Flow process chart (man-type, material-type and equipment type): This is the use of symbols and description to chart the sequence of work. The process, then, show what is happening at different stages. The distances and time may be given.

2) Two hands process charts

Multiple activity charts: This technique is used to solve problems where a number of items are dependent on each other. The aim is to reduce idle times by using the optimum number of each item. It depicts the occupied times-broken down into the number of different activities and the idle times both for the original and proposed methods of doing the job.

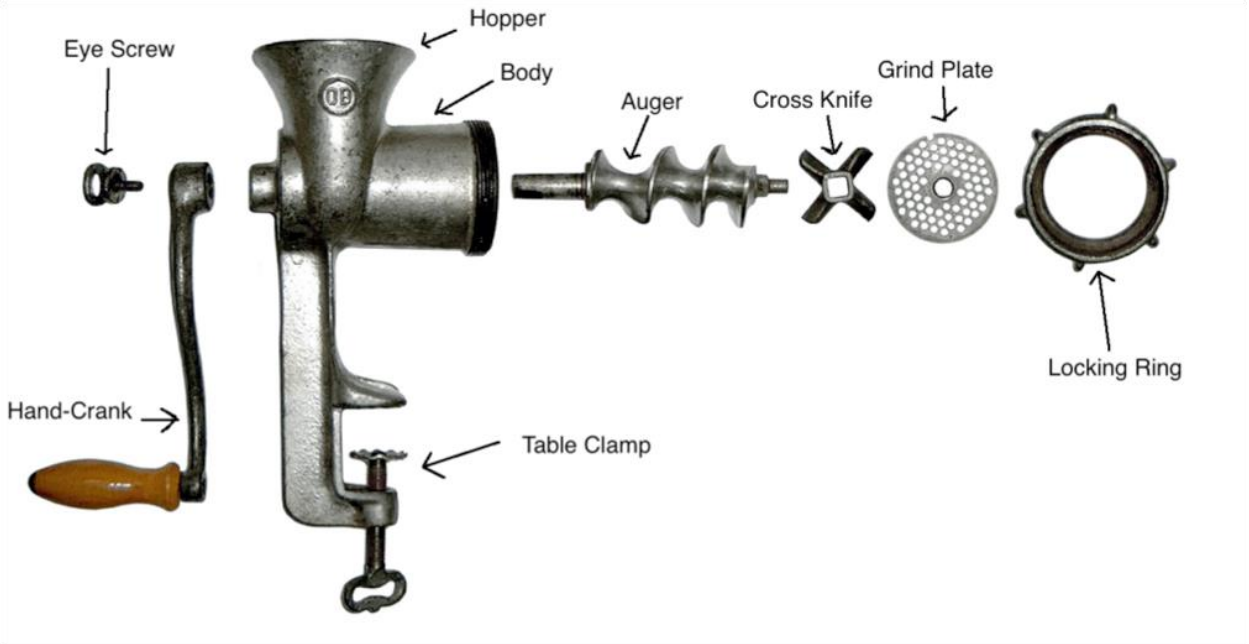
 - **Diagrams and models (2-D)**

1) **Flow diagrams**, which is the use of symbols for flow process charts, superimposed on drawings and the "descriptions" are not necessary.
2) **String diagrams**, which is used for solving movement problems since it shows congestions and excessive distances.

7. ASSEMBLY CHART

- It is an analog model of the assembly process.
- Circles with a single link denote basic components, circles with several links denote assembly operations/subassemblies, and squares represent inspection operations.
- The easiest method to constructing an assembly chart is to begin with the original product and to trace the product disassembly back to its basic components.

- **Assembly of Manual Meat Mincer:**
 - In first station, insert auger in grinder body.
 - Then in second station, hold the handle and insert an eye screw in it. Tighten it at the back of body and pass it to next station.
 - In third station, fix a grinding plate in front of cross knife.
 - In the end station, fix a locking ring at the end of grinder body.



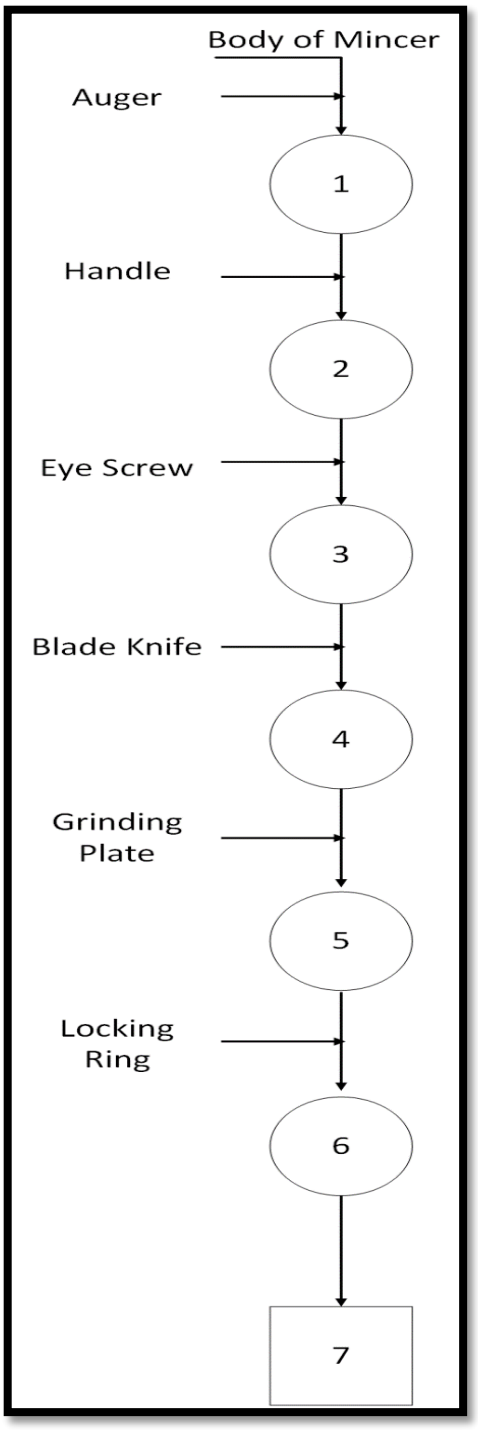
- **Assembly Line Flow Chart of Manual Meat Mincer:**



8. OPERATION / OUTLINE PROCESS CHART

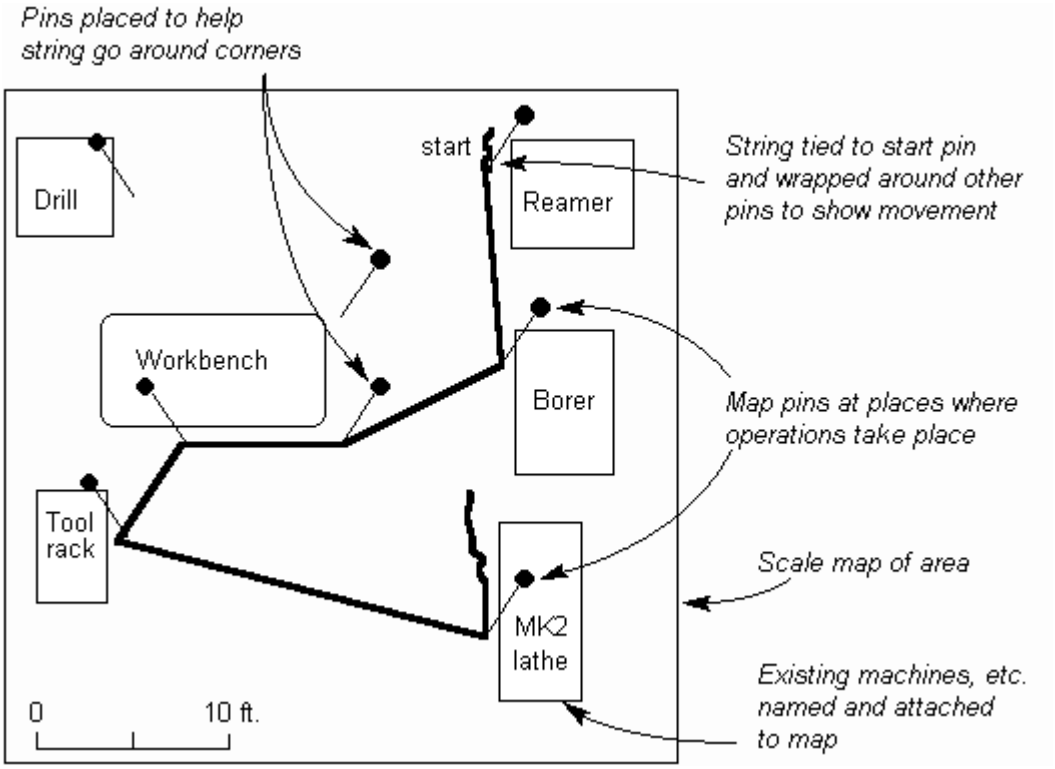
The operation process chart shows the chronological sequence of all operations, inspections, time allowances, and materials used in a manufacturing or business process, from the arrival of raw material to the packaging of the finished product.

- The chart depicts the entrance of all components and subassemblies to the main assembly.
- Two symbols are used in constructing the Operation Process Chart:
 - An operation and an inspection.
 - Operations charts show the introduction of raw materials at the top of the chart on a horizontal line.



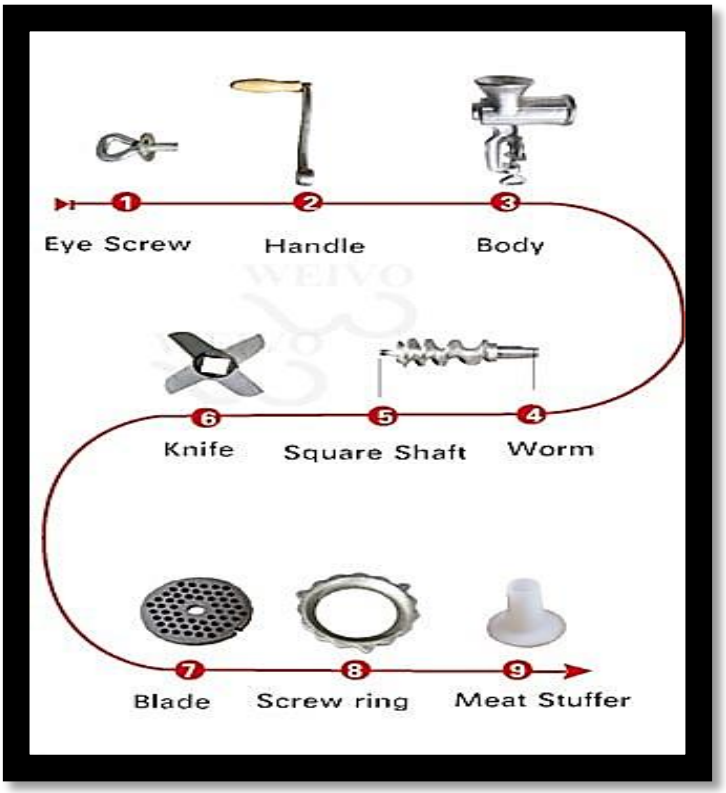
9. STRING DIAGRAM

String Diagram is a scaled plan of the shop. Location of Machines and various Facilities are drawn to scale in a drawing sheet. Pins are fixed at the various WorkCentres in a drawing sheet. A Continuous thread or string is taken round the pins where the material or worker moves during the process.

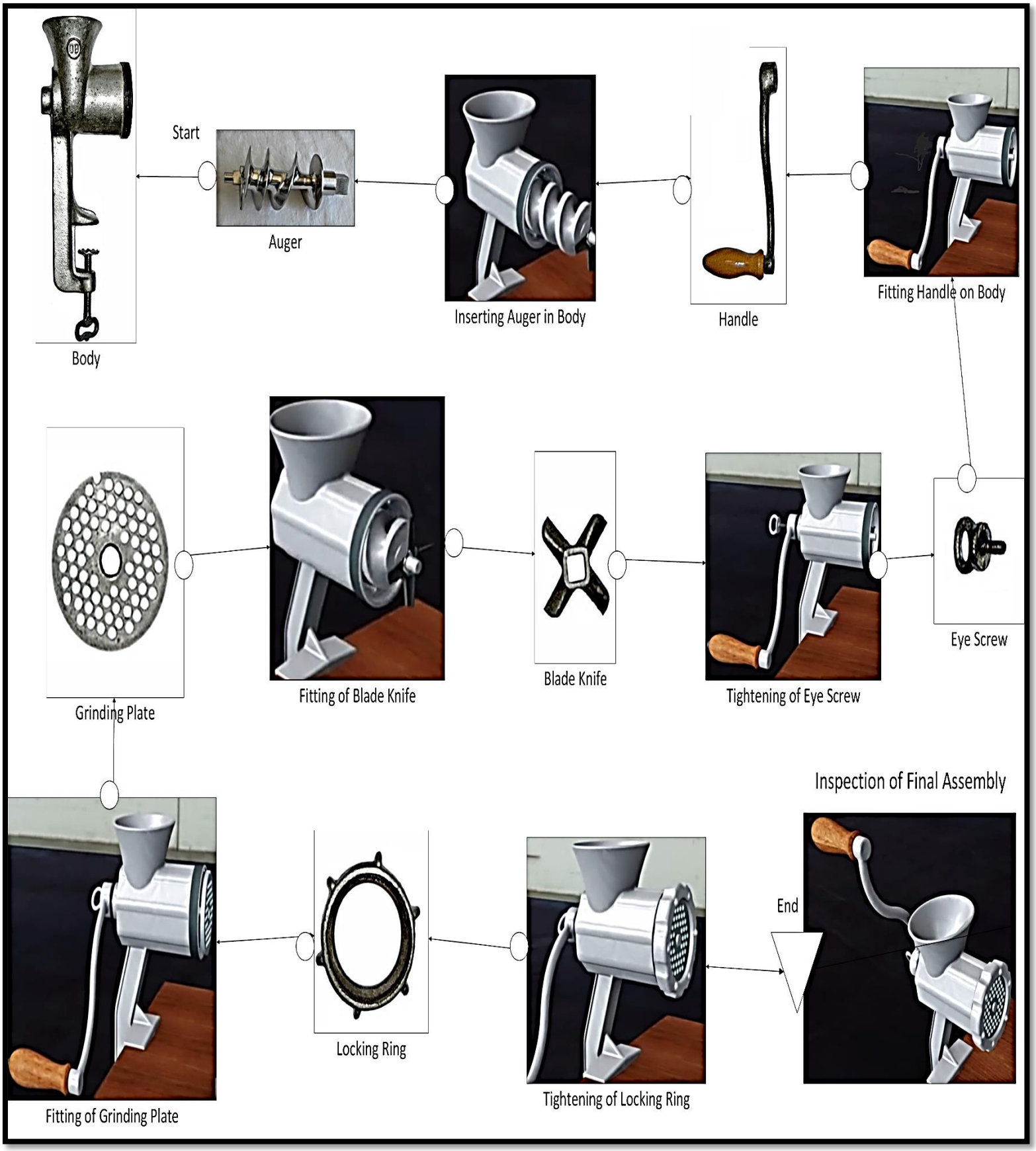


- **String Diagram of Assembly Line of Meat Mincer:**

Assembly Line of Manual Meat Mincer is:



STRING DIAGRAM:



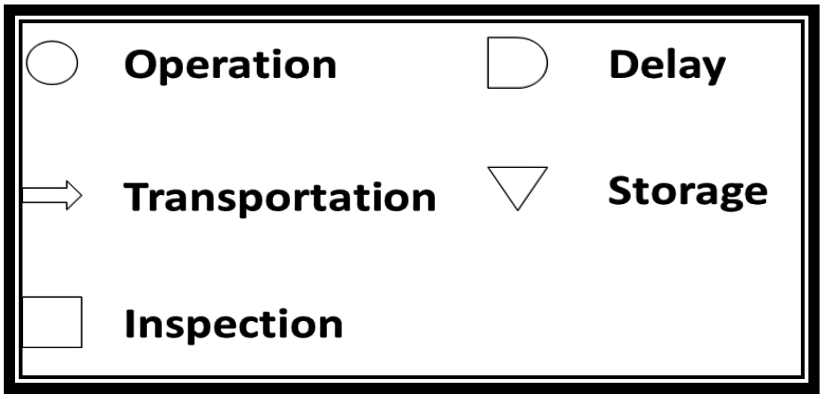
10.FLOW PROCESS CHART

The **flow process chart** is a graphical and symbolic representation of the activities performed on the work piece during the operation in Industrial Engineering. A Process Flow Diagram (PFD) is a type of flowchart that illustrates the relationships between major components at an industrial plant. They use a series of symbols and notations to depict a process. The symbols vary in different places, and the diagrams may range from simple, hand-drawn scrawls or sticky notes to professional-looking diagrams with expandable detail, produced with software.

A flow process chart is a chart of all the activities involved in a process. It is similar to an operations process chart, except that more detail is shown by including transportations and delays as well as operations, inspections, and storages.

Not usually used for entire assemblies, it is used for just one component (or operator)

- Process charts summarizes the whole process
- They are used to compare the existing and the proposed methods
- Process is observed, who, what, where, when, and how questions are asked
- Every detail is understood and the chart of the existing situation is drawn
 - **FLOW PROCESS CHART SYMBOLS**



 - **EXPLAINATION OF SYMBOLS**



Occurs when an object is intentionally changed in one or more of its characteristics
Usually occurs at a machine or a work station
Drilling, Painting, Data Entry, Cutting, Sorting, etc.



Occurs when an object is moved from one place to another
Except when the movement is part of an operation or an inspection
Using elevator, carrying, moving with material handling devices



Occurs when an object is examined for identification or is compared with a standard as to quantify or quality
Examine the quantity or quality, read steam gauge on boiler, detect the defectives.



Delay

Occurs when the immediate performance or the next planned action does not take place
Work In Process inventory waiting to be processed, Employee waiting for an elevator, Waiting for accumulation of a certain quantity for packaging



Storage

Occurs when an object is kept under control such that its withdrawal requires authorization
Bulk storage of raw material, finished products inventory, archived documents

- **Purpose and Benefits**

A Process Flow Diagram has multiple purposes:

- To document a process for better understanding, quality control and training of employees.
- To standardize a process for optimal efficiency and repeatability.
- To study a process for efficiency and improvement. It helps to show unnecessary steps, bottlenecks and other inefficiencies.
- To model a better process or create a brand-new process.
- To communicate and collaborate with diagrams that speak to various roles in the organization or outside of it.

- **How to Research the Process Flow**

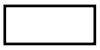
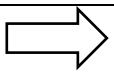
1. Define the scope of your process to be studied and what you hope to gain.
2. Decide on what level of detail is needed for your purposes. For a sophisticated process, different versions of the diagram may be drawn to communicate with people in different roles.
3. For an advanced process such as at an industrial plant, the research may be done through a project team, quality control group or a consultant. For a smaller, more basic process, you might do this yourself, perhaps even starting with sticky notes.
4. Study the equipment, activities and relationships through observation and interviews. If you're modeling a brand-new process, study whatever data is available, including standards for whatever is being produced in the process.
5. Draw a draft diagram and confirm it with people involved in the process. Make any necessary changes, additions or deletions in collaboration with them.
6. Now the diagram(s) can be used for its intended purpose of documentation, quality assurance, improvement or whatever other goal there might be.

- **Tips for Process Flow Diagrams**

1. These diagrams can have a lot of value for even a basic process. Don't worry about the chart itself at first. Just capture the information on sticky notes or sheets of paper.
2. Move on to diagram software once you have your information.. The software also may help you to highlight missing data in your diagram.
3. Be consistent with your symbols to avoid confusion. Remember who your intended audience is, and do whatever makes the most sense to give them what they need for the intended purpose. If you're using diagram software, it will include a set of symbols to use.
4. Include a symbol key on your diagram for clarity.

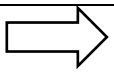
i. Worker Process Chart

The Worker Process Chart is used to analyze the activities of a worker around the facility

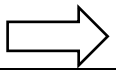
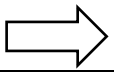
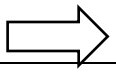
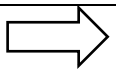
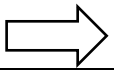
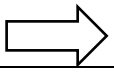
NAME	SYMBOLS
Operation	
Inspection	
Move	
Delay	

ii. Material Process Chart

The Material Process Chart is used to analyze the Flow of Material around the facility.

NAME	SYMBOLS
Operation	
Inspection	
Move	
Delay	
Storage	

11.Manual Meat Grinder Flow Process Chart:

Sequence	Activity Description	Symbol	Time(sec)
1	Fix the clamp on table		5
2	Pick the auger		2
3	Fix Auger in Grinder Body		7
4	Pick up the handle		2
``5	Fix it in back of grinder		9
6	Pick up eye screw		1
7	Tighten up it at the back of handle		19
8	Pick the cross Knife		2
9	Place it in front of auger		6.5
10	Pick the grinding Plate		2
11	Place it in front of cross knife		5
12	Pick up the Locking ring		2
13	Tight it on the end of Grinder body		18
14	Check all the components tighten well		12

12. LEFT HAND - RIGHT HAND CHART

Useful in analyzing the work performed by one person at one specific workstation. As the name implies, the chart follows the motion of the left and right hands of one operator. Each hand of the worker is treated as an activity. Each hand's activities are broken into work elements and plotted side by side on a time scale.

Lists the work performed simultaneously by each hand.

 To assist in finding a better method of performing the task and

 To train the operator in the preferred method.

- **SYMBOLS USED:**
 The using symbols are given below:

Symbols	Description	
O	Operation	
	Inspection	
	Move	
Đ	Delay	
∇	Store	

Sr #	Left Hand						Right Hand					
	Description	Symbols					Symbols					Description
		O			Đ	∇	O			Đ	∇	
1	Hold					•	•					Pick the Body
2	Hold					•	•					Set the Body
3	Hold					•			•			Reach for auger
4	Hold					•			•			Move the auger to Grinder body
5	Hold					•	•					Fit the Auger in Body
6	Reach for the handle			•							•	Hold
7	Hold					•			•			Move it to the back of body
8	Hold					•	•					Fit on the back of Body

9	Reach for the eye screw			•							•	Hold
10	Hold					•			•			Move it on the Back of Handle
11	Hold					•	•					Tight the Eye Screw
12	Reach for the cross knife			•							•	Hold
13	Hold					•			•			Move the blade knife to Auger
14	Hold					•	•					Fit it in front of Auger
15	Hold					•			•			Reach for the grinding plate
16	Hold					•			•			Move it in front of cross knife
17	Hold					•	•					Fit plate on Auger in front of Blade Knife
18	Reach for the locking ring			•							•	Hold
19	Hold					•			•			Move it in front of Body
20	Hold					•	•					Tight the Locking Ring
21	Hold					•		•				Inspect the Assembly properly
22	Move to the Storage			•					•			Move to the Storage

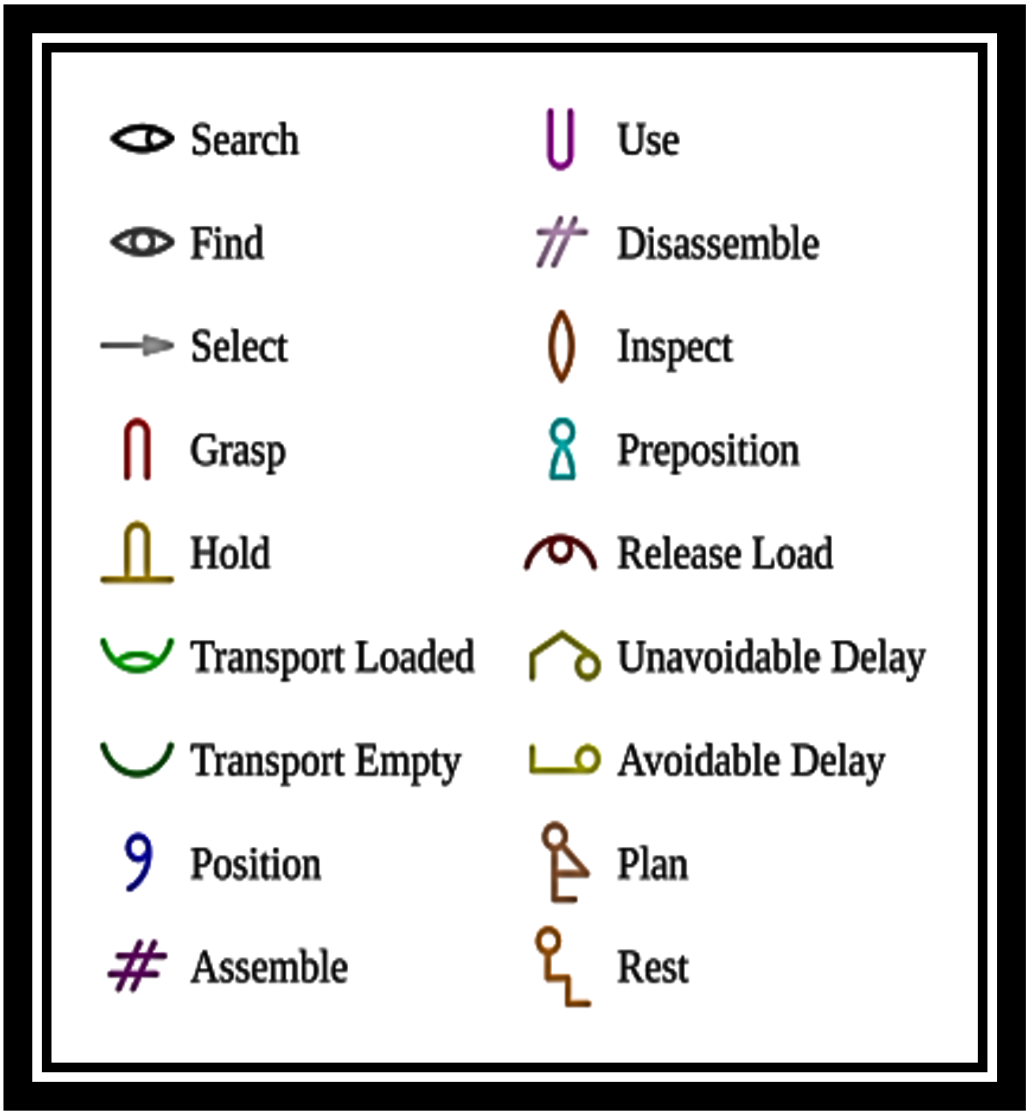
13.SIMULTANEOUS MOTION (SIMO) CHART

"SIMO" stands for simultaneous-Motion Cycle chart. It is one of micro motion study devised by Gilbreth and it presents graphically the separable steps of each pertinent limb of the operator under study. It is an extremely detailed left and right hand operation chart.

SIMO chart is another **Left-Right Handed Chart** with the difference that it is drawn to time scale and in terms of basic motion elements called **Therbligs**. The basic motion elements are **17**-types of motions that are called therbligs named by the Gilberth.

SIMO chart employs therbligs which are of microscopic nature where as a process chart uses symbols like operation, inspection, transportation etc. which are macroscopic nature.

It is carried out for a very short cycle, highly repetitive cycle. In this study a motion picture camera can be used for recording motions performed by an operator.



Sr #	Effective Therbligs		Sr #	Non-effective Therbligs	
	Therblig	**Symbol**		**Therblig**	**Symbol**
1	Transport Empty	TE	10	Hold	H
2	Transport Load	TL	11	Pre-position	PP
3	Grasp	G	12	Position	P
4	Release Load	RL	13	Search	Sh
5	Use	U	14	Select	St
6	Assemble	A	15	Plan	Pn
7	Dis-assemble	DA	16	Un-avoidable Delay	UD
8	Inspect	I	17	Avoidable dealy	AD
9	Rest	R			

- **Construction of "SIMO" Chart:**

The SIMO chart for left hand and right hand analysis sheet inform about the degree of participation of both the hands. The time for each Therblig recorded on the analysis sheet may be shown to scale by means of a SIMO chart. Either the SIMO chart may be prepared independently or the chart may be constructed from the data available on the analysis sheet.

Sr #	Left Hand		Right Hand	
	Description	**Symbols**	**Symbols**	**Description**
1	Idle	AD	TE	Reach for Body
2	Idle	AD	Sh	Search for Body
3	Idle	AD	S	Select the Body
4	Idle	AD	G	Grasp the Body
5	Hold	H	TL	Move the Body
6	Hold	H	P	Position the Body
7	Hold	H	RL	Set the Body
8	Hold	H	TE	Reach for auger
9	Idle	AD	Sh	Search for auger
10	Idle	AD	S	Select the Auger
11	Idle	AD	G	Grasp the Auger

12	Hold	H	TL	Move the auger to Grinder body
13	Hold	H	P	Position the Auger
14	Hold	H	A	Fit the Auger in Body
15	Reach for the handle	TE	AD	Idle
16	Search the Handle	Sh	AD	Idle
17	Select the Handle	S	AD	Idle
18	Grasp the Handle	**G**	AD	Idle
19	Move it to Right Hand	TL	G	Grasp from Left Hand
20	Hold	H	TL	Move it to the back of body
21	Hold	H	P	Position it on the back of Body
22	Hold	H	A	Fit on the back of Body
23	Reach for the eye screw	TE	AD	Idle
24	Search for the Eye Screw	Sh	AD	Idle
25	Select the Eye Screw	S	AD	Idle
26	Grasp the Eye Screw	G	AD	Idle
27	Move it to the Right Hand	TL	G	Grasp from left hand
28	Hold	H	A	Move it on the Back of Handle
29	Hold	H	P	Position it
30	Hold	H	A	Tight the Eye Screw
31	Reach for the cross knife	TE	AD	Idle
32	Search for Cross Knife	Sh	AD	Idle
33	Select the Cross Knife	S	AD	Idle
34	Grasp the Cross Knife	G	AD	Idle

35	Move it to Right Hand	TL	G	Grasp from Left Hand
36	Hold	H	TL	Move the blade knife to Auger
37	Hold	H	P	Position it
38	Hold	H	A	Fit it in front of Auger
39	Hold	H	TE	Reach for the grinding plate
40	Idle	AD	Sh	Search for Grinding Plate
41	Idle	AD	S	Select the Grinding Plate
42	Idle	AD	G	Grasp the Grinding Plate
43	Hold	H	TL	Move it in front of cross knife
44	Hold	H	P	Position it
45	Hold	H	A	Fit plate on Auger in front of Blade Knife
46	Reach for the locking ring	TE	AD	Idle
47	Search for the Locking Ring	Sh	AD	Idle
48	Select the Locking Ring	S	AD	Idle
49	Grasp the Locking Ring	G	AD	Idle
50	Move it to Right Hand	TL	G	Grasp from Left Hand
51	Hold	H	TL	Move it in front of Grinding Plate
52	Hold	H	P	Position it
53	Hold	H	A	Tight the Locking Ring
54	Inspect	I	I	Inspect

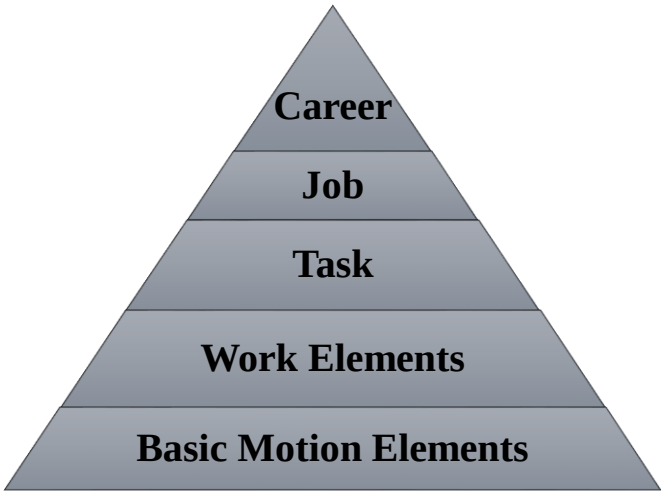
14.Time Study:

A time and motion study (or time-motion study) is a business efficiency technique combining the Time Study work of Frederick Winslow Taylor with the Motion Study work of Frank and Lillian Gilbreth (the same couple as is best known through the biographical 1950 film and book Cheaper by the Dozen)

Time study is a work measurement technique for recording the time of performing a certain specific job or its element carried out under specific condition and for analyzing the data so as to obtain the time necessary for an operator to carry out at a defined rate of performance.

- **Work / Task:**

The work is the physical or mental activity that is performed for the useful objective with the help of skills and knowledge. The pyramidal structure is given below.



Task is our case is the Assembly Line of Meat Mincer in which Body, Auger, Handle, Eye Screw, Knife Blade, Grinding Plate and Locking Ring are assembled to give the final product "Meat Mincer". This task has several Work Elements.

- **Work Element:**

Work element basically represents the small portions of the total work that must be accomplished to assemble the product.

The Work Elements of the Assembly of Meat Mincer are:

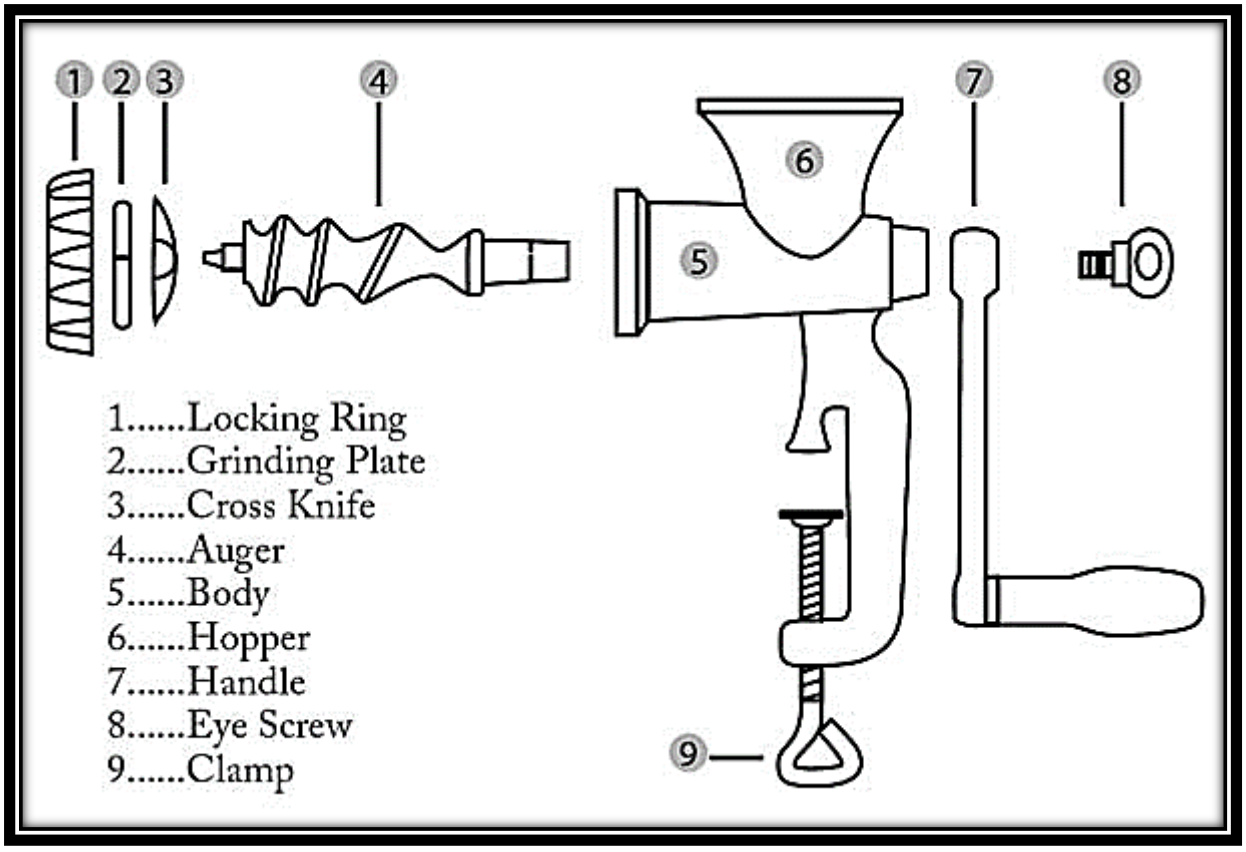
i. **Workstation # 1**
Inserting Auger in Body

ii. **Workstation # 2**
Fitting Handle on the Body
Tightening the Eye Screw on Handle

iii. **Workstation # 3**
Inserting Blade and Fitting it in
Inserting Grinding Plate

iv. **Workstation # 4**
Tightening of Locking Screw

v. **Workstation # 5**
Inspection



I Cycle Time:

Cycle time is the total time from the beginning to the end of your process, as defined by you and your customer. Cycle time includes process time, during which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spent waiting to take the next action.

Cycle Time is the total time require to complete a process. It is the period to complete a process. It is the period to complete one cycle of an operation.

In either case, the task can be divided into work elements that consist of logical grouping of motions performed by the worker.

The Cycle Time $\boldsymbol{T_c}$ is therefore the sum of all work elements times.

Cycle time in this case is $\boldsymbol{T_c}$ **= 76.5s or 1.275min**

II Rating:

Rating of something based on comparative analysis of their quality, standard of performance.

The performance rating of a process is concerned with determining normal pace during the work portion of an average day and must, therefore, consider the fatigue recovery aspects of allowance (non-work) times occurring during the day.

Rating is the performance measure that describes that how much effectively and accurately a worker is performing a task. Rating is given by highly experienced person. Rating may be greater than or less than the 100 %. The formula for rating is given below.

$$Rating\ factor = \frac{Observe\ Performance}{Normal\ Performance}$$

Rating in this case is **100%.** Because the pace of working of Workers is Highly Normal because they are experienced in their tasks.

III Normal Time:

Time required by a worker to complete a task.

The time required by a trained worker to perform a task at a normal pace. The total of all the normal elemental times constituting a cycle or operation. Also known as Basic Time.

$\boldsymbol{T_n}$**=** Cycle Time * Rating

$\boldsymbol{T_n}$**= 76.5s** * 1

$\boldsymbol{T_n}$**= 76.5s**

IV Allowance:

PFD Allowance(A_{PFD}) is the adjustment done to the normal time to obtain the standard time for the purpose to recover the lost time due to personal needs, fatigue, and unavoidable delays

An Allowance factor represents time lost due to Personal Factors, Shift Adjustments, Improper Equipment, Fatigue and related issues.

Allowances also includes Avoidable delays and Unavoidable Delays.

Types of Allowances:

a) Relaxation Allowances:

Relaxation allowance is an addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of allowance will depend on the nature of the job.

b) Personal needs

This allowance provides for the necessity to leave the workplace to attend to personal needs such as washing, going to the lavatory or fetching a drink

c) Basic fatigue

This allowance, always a constant is given to take account of the energy expended while carrying out work and to alleviate monotony.

In our case of Assembly Line, the PFD Allowance of our Assembly Line is:

$$A_{PFD} = 15\%$$

V Standard Time:

The standard time is the time required by an average skilled operator, working at a normal pace, to perform a specified task using a prescribed method.

Standard Time is the sum of Basic or Normal Time and Allowance of Basic Time.

For Allowance of 15%, Standard time is expressed as:

$$T_{std} = \text{Normal Time } (1+A_{PFD})$$

$$T_{std} = 76.5\text{s } (1+0.15)$$

$$T_{std} = 87.975\text{s} \quad \text{or} \quad 1.46\text{min}$$

			Rating = 100%	Allowances (15%)
Work Station	**Work Elements**	**Cycle Time**	**Normal time= CT *Rating**	**Standard Time**
Workstation # 1	Inserting Auger in Body	7	7	8.05
		7	**7**	**8.05**
Workstation # 2	Fitting Handle on the Body	9	9	10.35
	Tightening the Eye Screw on Handle	19	19	21.85
		28	**28**	**32.2**
Workstation # 3	Inserting Blade and Fitting it in	6.5	6.5	7.475
	Inserting Grinding Plate	5	5	5.75
		11.5	**11.5**	**13.225**
Workstation # 4	Tightening of Locking Screw	18	18	20.7
		18	**18**	**20.7**
Workstation # 5	Inspection	**12**	**12**	**13.8**
Total Time		**76.5 (1.275min)**	**76.5(1.275min)**	**87.975(1.46min)**

VI Split Time / Lap Time

Split time is the time that can be noted at every moment. Total time divided into smaller parts defined as **Split Time.**

While the time calculated at the end of the whole process or task gives us the **Lap Time.**

VII Bottleneck

The point at which an industry or economic system has to slow its growth because one or more of its components cannot keep up with demand.

The phenomenon where the performance or the capacity of the entire system is limited by a single resource.

Bottleneck is a condition in the un-balanced assembly line. The bottleneck station has cycle time or processing time that is higher than the other workstations. In this situation, due to the uneven distribution of the work to the workstations, some stations will be in blocking condition and some will be in starving condition. Thus overall production will depend on that station. The daily production of the line depends on that station the number of outputs from this station will be the line productivity.

In our case of Assembly Line, Bottleneck Operation is at "**Workstation # 2**" '**Tightening the Eye Screw on Handle'**.

VIII Utilization of Worker

A **utilization** method that attempts to maximize the efficiency of a company's employees. This can be accomplished by a variety of methods, including training an employee in multiple areas so that they can switch from one role to another depending upon where they are most needed at a given time.

To **calculate** the **utilization** rate is to take the number of billable hours and divide by a fixed number of hours per week.

Utilization = number of units produced * Product SAM /actual min. worked

Utilization = 100 * 1.74 / 210

Utilization = 0.8285

Utilization = 82.85 %

IX Work In Process (WIP)

Work in Process is the type of the inventory which is not finished and it is necessary for the continuity of the process in any assembly line.

Work in process (WIP), work in progress (WIP), goods in process, or in-process inventory are a company's partially finished goods waiting for completion and eventual sale or the value of these items. These items are either just being fabricated or waiting for further processing in a queue or a buffer storage. Work in process in our case is calculated as given below.

WIP = Total piece loaded – Total output in line

WIP = 4 – 1 = 3 pieces

X Operator Efficiency:

Machine operator efficiency (MOE) is a lean manufacturing term used to describe the performance of an employee who operates industrial machinery. The operator's efficiency is measured as the time spent producing product divided by the time the operator is on duty.

It is the actual work rate of the human operator relative to work rate expected under standard or normal performance.

- Operator efficiency Represented by (**η**).

η = Total work product *op. SAM * 100 / Total min worker.

XI Production Rate:

It is the rate in which all the products of a daily work is being complete.

In manufacturing, the number of goods that can be produced during a given period of time. Alternatively, the amount of time it takes to produce one unit of a good. In construction, the rate at which workers are expected to complete a certain segment, such as a road or building.

XII Takt time:

Takt time is the rate at which a finished product needs to be completed in order to meet customer demand.

Takt time = available production rate per day/customer demand per day

15.Performance Measures:

a) Line Efficiency:

The line output are 1000 units per day.

$$Line\ Efficiency\% = \frac{Line\ Output * Product\ SAM * 100}{Total\ no\ of\ Operator * minutes\ worked}$$

$$Line\ Efficiency\% = \frac{1000 * 1.46 * 100}{7 * 480}$$

=43.45%

b) Daily line Target:

Production quantity produced by a qualified worker in a day at standard performance is known as ***daily*** production ***target***. So in case of line target, no. of operators, time and line efficiency came in play.

$$Daily\ line\ target = \frac{total\ working\ \text{minutes}\ in\ \ a\ day * No\ of\ \ operators * line\ efficiency\%}{Product\ SAM}$$

$$Daily\ line\ target = \frac{480 * 8 * 0.3476}{1.46}$$

=1143 units/day

c) Individual operator Target:

$$Individual\ operator\ target = \frac{Total\ working\ minutes\ in\ a\ day * Line\ efficiency\%}{Operation\ SAM}$$

d) Operator Efficiency:

Machine **operator efficiency** (MOE) is a lean manufacturing term used to describe the performance of an employee who operates industrial machinery. The **operator's efficiency** is measured as the time spent producing product divided by the time the **operator** is on duty.

$$Operator\ Efficiency\ \%(individual) = \frac{Total\ unit\ produced * Operation\ SAM * 100}{Total\ \ minutes\ worked}$$

			Rating = 100%	Allowances (15%)		
Work Station	**Work Elements**	**Cycle Time**	**Normal time= CT *Rating**	**Standard Time**	**Worker Efficiency =(Total unit produced *operation SAM) /total min worked**	**Individual operator target**
Workstation # 1	Inserting Auger in Body	7	7	8.05	86.87%	1554
		7	**7**	**8.05**		
Workstation # 2	Fitting Handle on the Body	9	9	10.35	86.9%	1209
	Tightening the Eye Screw on Handle	19	19	21.85	87%	573
		28	**28**	**32.2**		
Workstation # 3	Inserting Blade and Fitting it in	6.5	6.5	7.475	86.89%	1674
	Inserting Grinding Plate	5	5	5.75	86.88%	2176
		11.5	**11.5**	**13.225**		
Workstation # 4	Tightening of Locking Screw	18	18	20.7	86.825%	604
		18	**18**	**20.7**		
Workstation # 5	Inspection	**12**	**12**	**13.8**	87%	907
Total Time		**76.5 (1.275 min)**	**76.5(1.275min)**	**87.975(1.46 min)**		

e) Machine Productivity:

$$Machine\ Productivity = \frac{Line\ Output\ in\ pieces}{Number\ of\ Machine\ used}$$

In manual assembly line, this ratio is not applicable.

f) Labor Productivity:

$$Labor\ Productivity = \frac{Line\ Output\ in\ pieces}{Number\ of\ workers\ (Including\ Operators + helpers)}$$

$$Labor\ Productivity = \frac{1000}{7}$$

=143 units/worker/day

g) Cost per Minute:

The average salary of the worker is 20,000 Rs. There is 25-26 working days in the line and 7 workers working in the line. So, the cost incurred in labors

$$Cost\ per\ minutes = \frac{Total\ cost\ incurred\ in\ labour}{Total\ available\ working\ minutes\ in\ a\ Day * No\ of\ Labors}$$

It is defined as;

CPM = Total cost incurred in labor / Total working minutes in a day * Total no of workers

CPM = 5600 /480*7

CPM = 1.66 Rs/ min

h) Production cost per Minute

$$Production\ Cost\ per\ minutes = \frac{Total\ Production\ cost\ incurred\ in\ a\ Day}{Total\ Products\ Produced\ in\ a\ Day}$$

= 5600 / 1000 = 5.6 Rs/min

i) Man to machine ratio

$$Man\ to\ Machine\ Ratio = \frac{Total\ workforce\ in\ a\ factory}{No\ of\ utilized\ machines}$$

Since we are dealing with manual assembly line, so man to machine ratio is not applicable.

16. ASSEMBLY-LINE BALANCING: An Effective Tool for Improving Productivity

1. What is assembly-line balancing?

- To a workstation within an assembly line in order to meet the required production rate and to achieve a minimum amount of idle time.
- Line balancing is the procedure in which tasks along assigning each task the assembly line are assigned to work station so each has approximately same amount of work.

2. Unbalance Line and Its effect

- High work load in some stages (Overburden)
- Maximizes wastes (over-processing, inventory, waiting, rework, transportation, motion)
- High variation in output
- Restrict one piece flow
- Maximizes Idle time
- Poor efficiency

3. Balanced Line and its effect

- Promotes one piece flow
- Avoids excessive work load in some stages (overburden)
- Minimizes wastes (over-processing, inventory, waiting, rework, transportation, motion)
- Reduces variation
- Increased Efficiency
- Minimizes Idle time

4. How Can Assembly-Line Balancing Help Organization?

- Increased efficiency
- Increased productivity
- Potential increase in profits and decrease in costs

5. Steps in Balancing an Assembly Line

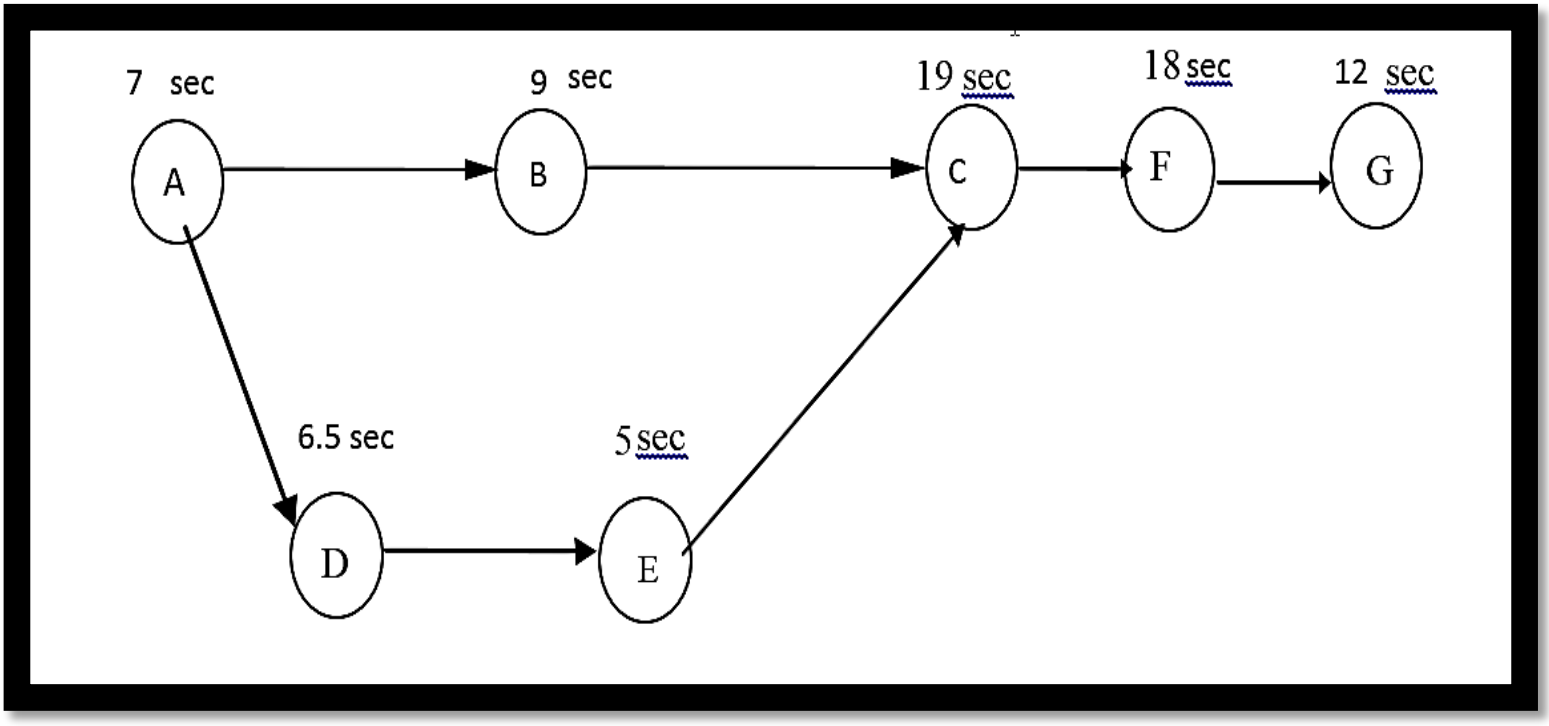
1. List the sequential relationships among tasks and then draw a precedence diagram.
2. Calculate the required workstation cycle time.
3. Calculate the theoretical minimum number of workstations.
4. Choose a primary rule that will determine how tasks are to be assigned to workstations.
5. Beginning with the first workstation, assign each task, one at a time, until the sum of the task times is equal to the workstation cycle time or until no other tasks can be assigned due to sequence or time restrictions.
6. Repeat step 5 for the remaining workstations until all the tasks have been assigned to a workstation.
7. Evaluate the efficiency of the line balance.
8. Rebalance if necessary.

Assembly-Line Balancing

Task	Task Time (in seconds)	Task Description	Precedence Constraints
A	7	Inserting Auger in Body	—
B	9	Fitting Handle on the Body	**A**
C	19	Tightening the Eye Screw on Handle	**B , E**
D	6.5	Inserting Blade and Fitting it in	**A**
E	5	Inserting Grinding Plate	**D**
F	18	Tightening of Locking Screw	**E**
G	12	Inspection	**F**

List the sequential relationships among tasks and then drawing a precedence diagram

Stations	Work Elements	Precedence	Cycle Time (Min)	Sum Tc 0f Station (Sec)
1	A	-	7	7
2	B C	A B, E	9 19	28
3	D E	A D	6.5 5	11.5
4	F	C	18	18
5	G	F	12	12



Calculating theoretical number of work-station

Number of work-stations = Total work content time / Cycle time

Number of work-stations = 76.5 / 19

Number of work-stations = 4

Allowed number of work station = 4+1= 5 Solution

$$T_s = 28 \text{ sec}$$

$$\text{Delay Time} = \frac{wT_s - T_{wc}}{wT_s}$$

$$= \frac{5(28) - 76.5}{5(28)}$$

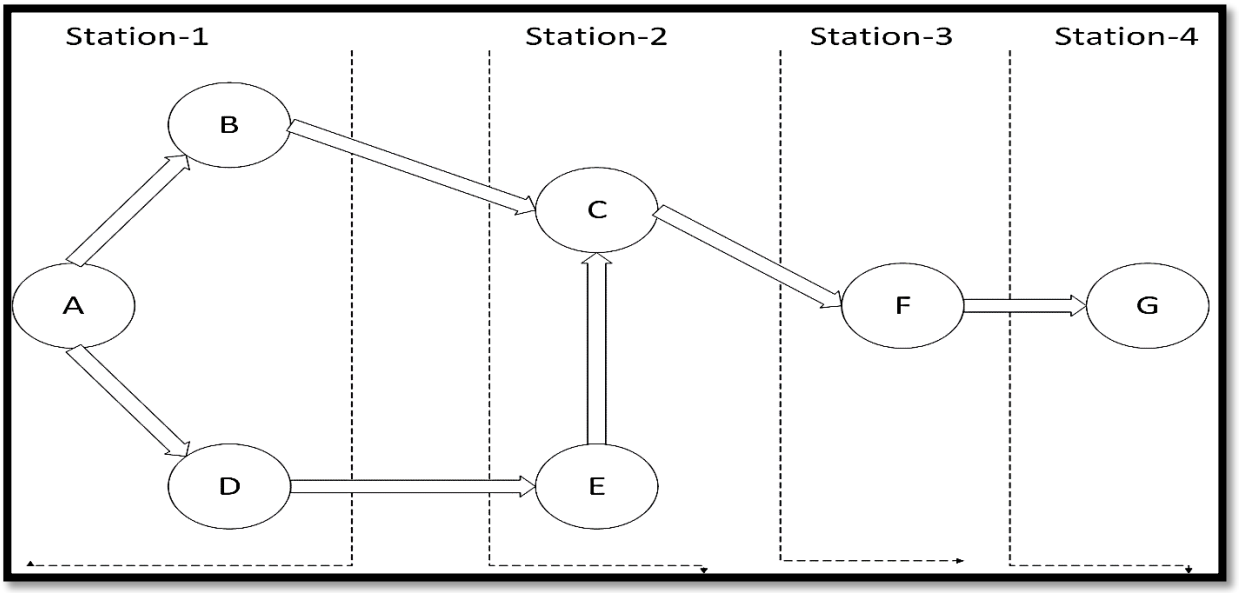
$$= 45.36\ \%$$

Line Efficiency = 1- Delay = 54.64 %

Largest Candidate Rule:

Stations	Work Elements	Precedence	Cycle Time (Min)	Sum Tc 0f Station (Sec)
1	A B D	-- A A	7 9 6.5	7
2	E C	D B, E	5 19	28
3	F	C	18	18
4	G	F	12	12

Improved Precedence:



$$T_s = \frac{480*60}{1200} = 24\text{sec}$$

$$\text{Delay Time} = \frac{wT_s - T_{wc}}{wT_s}$$

$$= \frac{4(24) - 76.5}{4(24)}$$

$$= 20.3\ \%$$

Line Efficiency = 1- Delay = 79.7 %

Calculate the theoretical minimum number of workstations.

NUMBER OF WORK STATIONS= (SUM OF TOTAL TASK TIMES) / (CYCLE TIME)

= 76.5 / 24 = 3.18 ≈ 4 (Rounded)

17. COMPARISON:

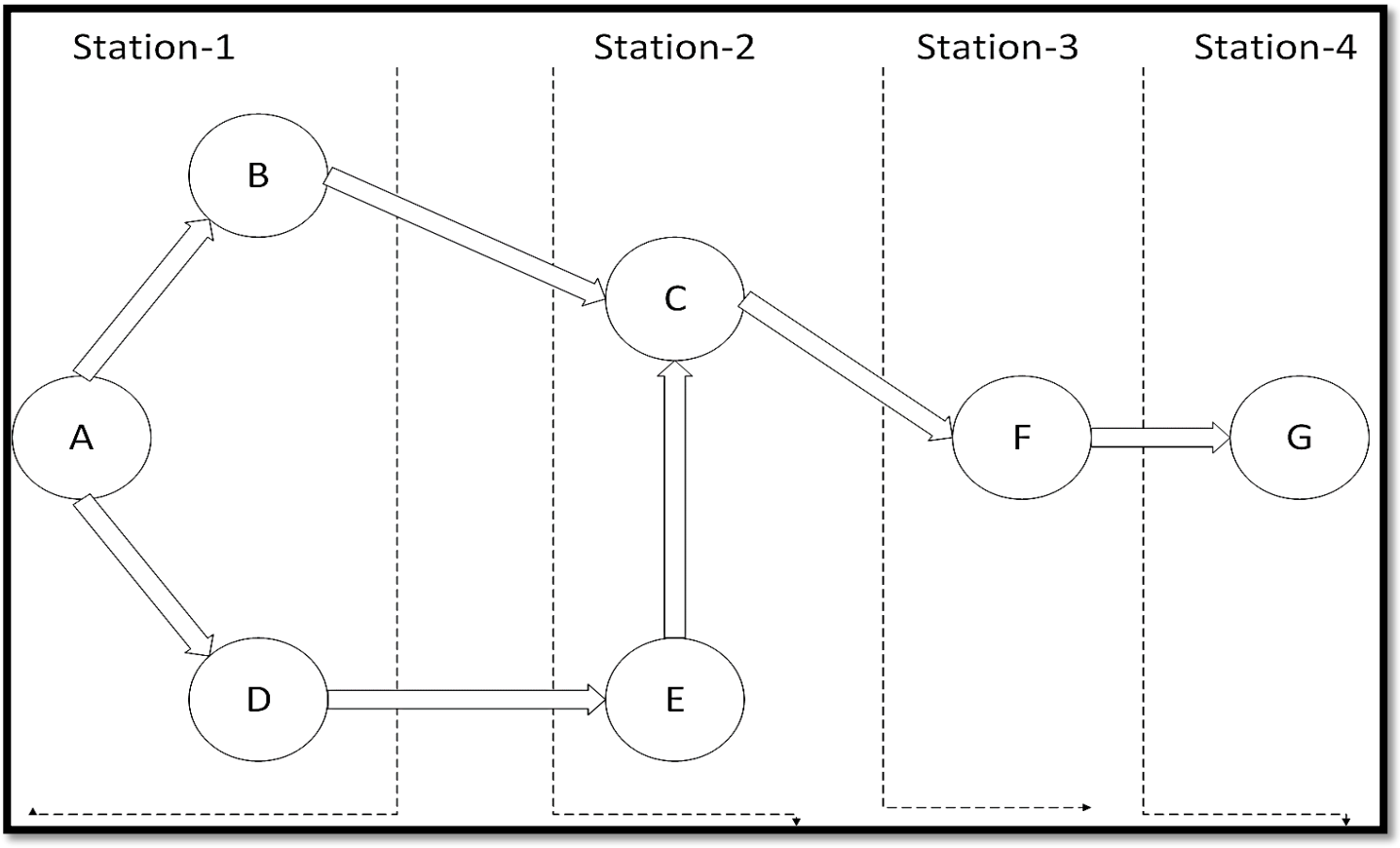
Our First Assembly Line has **more Delay**, hence, **Line Efficiency** is **Low** thus we were **unable** to achieve **Daily Line Target.** Using our first Precedence of Tasks of our Assembly Line we have **Delay** of **43.36%** and **Line Efficiency** of **54.64%** with **Theoretical Minimum Number of WorkStations** of **5.** Now this new Assembly Line has reduced the **Delay** from **43.36%** to **20.3% with Line efficiency** of **79.7%** and with **Theoretical Minimum Number of WorkStations** of **4.**

18. IMPROVEMENT:

1st.Improvement:

The 1st Improvement in the System of Assembly Line is the Balancing of Assembly Line by using **Largest Candidate Rule.**

The Improvement is the Sequencing of the Assembly Line Task as shown below and assigning the minimum feasible number of Workstations as given below diagrammatically:



2nd.Improvement:

The 2nd Improvement is actually a suggestion to improve the System of Assembly Line of Meat Mincer.

Suggestion is that we have to design a **Die** that perfectly fits the Body of the Mincer in upright position and each and every single worker of assembly line assemble his own assembly by just inserting the parts in it using both their hands and then use a Screw Tightener to fastly tight the screws. This will improve the assembly line and takes lesser time than before and helps to achieve the **Daily Line Target.**

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